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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B29C 65/02, H05B 6/10, 3/56

A1

(11) International Publication Number: WO 98/21023

(43) International Publication Date: 22 May 1998 (22.05.98)

(21) International Application Number: PCT/US97/04575

(22) International Filing Date: 17 March 1997 (17.03.97)

(30) Priority Data:
08/751,527 15 November 1996 (15.11.96) US

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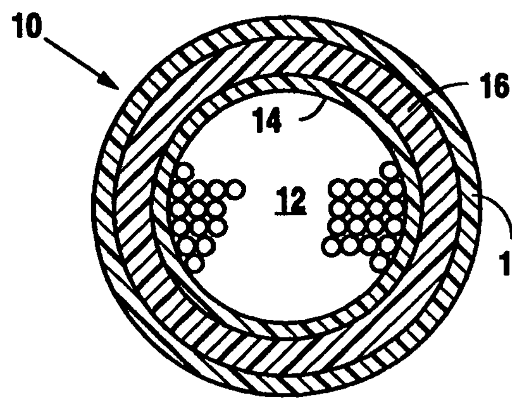
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: WIRE ASSEMBLY AND METHOD OF INDUCTION HEATING



(57) Abstract

A wire assembly and method of induction heating in which a composite coating containing a thermoplastic and susceptor particles is extruded over an electrical conductive wire. When an alternating current of an appropriate frequency is passed through the wire, the susceptor particles absorb energy from the alternating magnetic field which is generated by the electric current and thus are heated to the extent that they heat the surrounding thermoplastic as well as materials immediately adjacent to the thermoplastic. Thus, the composite-coated wire can be used to bond thermoplastic parts along a seam in which the wire is placed. In addition, the combination of wire and susceptor-loaded composite can be used to supply heat to activate a thermoset adhesive. The susceptor particles are optimally oriented to and positioned around the electrical conductive wire for absorption of the magnetic field because of the extrusion process and the configuration of the wire with surrounding composite containing the particles.

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WIRE ASSEMBLY AND METHOD OF INDUCTION HEATING

Field of the Invention

This invention relates to high frequency induction heating and, more particularly, to a wire assembly and method for utilizing high frequency induction heating for bonding thermoplastic materials and activating thermoset adhesives.

Background of the Invention

There are several known heating systems and methods for bonding thermoplastic materials and activating thermoset adhesives to bond articles together. For example, fusion bonding of thermoplastic materials is often used and generally involves the heating of the materials until they become molten at their sealing surfaces, thus causing the materials to flow together at the interfaces.

According to one type of fusion bonding, heat is applied to the thermoplastic article to be bonded by directly attaching heating elements or units to the material to be bonded, so that the material is heated when current is applied to, and flows through, the elements. Another known fusion bonding technique involves the use of radiant microwave energy to heat the material by dielectric polarization, hysteresis heating and/or resistive heating. Dielectric heating is still another known fusion bonding technique, in which two plates or electrodes create a varying electric potential (voltage) around or through the material to be heated. These techniques are, for the most part, equally applicable to the activation of thermoset adhesives to achieve the same results.

However, there are several disadvantages associated with various ones of the above type of techniques. For example, certain of the techniques do not lend themselves to applications in which heat has to be introduced into areas that are not easily accessible, and/or in which it is desirable to confine the heating to the area near the interface (or "bond line") between the articles to be bonded. Other disadvantages are that certain of the techniques do not work satisfactorily in situations where the articles to be bonded are too large for practical application of

heat to the whole article. Also, with certain of the techniques, it has been difficult to achieve uniform heating of the materials or the thermoset adhesive. Even more, certain of the techniques are relatively inefficient, thus requiring a relatively large amount of electrical power, and therefore often cannot be used with portable power sources, such as batteries.

An application in which heating at a bond line is required is the sealing of joined or spliced communication cable ends. Communication cables are typically constructed of a conductor bundle, surrounded by a metal strength and interference sheathing and an outer protective coating, typically of polyethylene. Although the term "conductor" and similar terms are sometimes used herein, it is to be understood that the terms refer here to not only electrical conductors, but also to any and all other materials and paths for communication, such as optic fibers and others. When such cables are spliced and rejoined, the strength and integrity of the rejoined cable is critical. An enclosure or closure body including end seals is used to sealingly surround the splice. A persistent problem in the use of splice closures and end seals involves the need for a complete seal about the splice, the end seals, the cables and the closure body.

Therefore, what is needed is a heating system and method for high frequency induction heating in which the heat can be introduced into areas that are not easily accessible, in which the heating must be confined to an area near the bond line, and/or in which the objects to be bonded are too large for applications of heat to the entire object. Also needed is a heating system and method of the above type which achieves uniform heating in an efficient manner.

Summary of the Invention

According to the present invention a layer of thermoplastic material containing susceptor particles is applied over an electrical conductor and the electrical conductor is placed in a heat exchange relationship to an object to be bonded. When electrical energy is applied to the electrical conductor to create an alternating magnetic field, the susceptor particles absorb the energy from the magnetic field and heat up and melt the thermoplastic material of the object to

enable it to be bonded to another object.

The advantages of the present invention include applicability to bonding applications in which the heating must be confined to an area near the bond line, when the objects to be bonded are too large for applications of heat to the entire object, and/or when the bond line is not easily accessible. Another advantage of the present invention is that the wire assembly achieves uniform heating in an efficient manner.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view of the wire assembly of the present invention.

Fig. 2 is an exploded, isometric view of two thermoplastic sheets to be bonded with the wire assembly of Fig. 1.

Fig. 3 is a view similar to that of Fig. 2 but showing the wire assembly of Fig. 1 applied to one of the sheets of Fig. 2.

Fig. 4 is an isometric view depicting the sheets of Fig. 2 bonded together.

Fig. 5 is a view similar to that of Fig. 3 but depicting another alternative embodiment of the present invention.

Fig. 6 is a view similar to that of Fig. 1 but depicting an alternative embodiment of the present invention.

Description of the Preferred Embodiment

An embodiment of the wire assembly of the present invention is shown, in general, by the reference numeral 10 in Fig. 1, and includes a stranded wire 12 of an electrically conductive material such as copper. An example of the size and specifications of the wire is 26 AWG 7/34 although other sizes and specifications would be equally applicable. Alternatively, the wire 12 may be a ribbon or tape or have other cross-sectional configuration.

An inner layer, or sleeve 14, of a thermoplastic material, such as high density polyethylene extends over the wire 12; a layer, or sleeve, 16 of a composite material to be described extends over the layer 14; and an outer layer, or sleeve of a thermoplastic material, such as high density polyethylene, extends over the layer 16. Preferably, the inner polyethylene layer 14 is extruded over the outer surface of the

wire 12, the layer 16 of composite material is extruded over the layer 14, and the outer polyethylene layer 18 is extruded over the layer 16. Since this type of extruding is well known in the art, it will not be described in any detail. For the purposes of a non-limiting example, the inner polyethylene layer 14 is eight mils thick, the composite layer 16 is twelve mils thick and the outer polyethylene layer 18 is eight mils thick.

The composite layer 16 consists essentially of a thermoplastic material, such as high density polyethylene, containing a plurality of electromagnetic susceptor particles disbursed throughout the thermoplastic material before the latter is extruded over the layer 14, in accordance with known technology. These susceptor particles are conventional, and can, for example, be in the form of ferrites (such as many of the ferrites manufactured by Steward Corporation of Chattanooga Tennessee) or any other types of susceptor particles as long as they absorb energy from the alternating magnetic field which is generated by an electrical current flowing through the wire 12, as will be described. As a result of this energy absorption, the susceptor particles generate heat in accordance with electromagnetic principles. As an example, the composite layer 16 consists of high density polyethylene with a 4% loading by volume of susceptor particles.

As an example of the application of the wire assembly 10 and the method of the present invention, Fig. 2 depicts two blocks, or sheets, 20 and 22 of a thermoplastic material, such as high density polyethylene, which can be bonded together in accordance with the present invention but which are shown separated in Fig. 3. As an example of their respective dimensions, both sheets are six inches square with the sheet 20 being one-half cm thick and the sheet 22 having a thickness of one cm. A relatively shallow channel 22a is provided in the upper surface of the sheet 22 and extends around the sheet near its outer periphery. A through opening 22b is provided in one corner of the sheet that extends from the channel 22a through a portion of the sheet.

As shown in Fig. 3, the wire assembly 10 is placed in the channel 22a of the sheet 22 with its end portions 10a and 10b extending through the opening 22b and

projecting outwardly from the sheet. If necessary, it is understood that pieces or rods (not shown) of polyethylene filler material are used to fill that part of the channel 22a not filled by the wire assembly 10. It is understood that these end portions 10a and 10b are connected to a source of alternating current (not shown) which will be described in further detail.

The sheet 20 is then placed over the sheet 22 as shown in Fig. 4 thus defining a bond line, shown by the reference letter L, at the juncture between the lower surface of the sheet 20 and the upper surface of the sheet 22. The projecting end portions 10a and 10b of the wire assembly 10 are connected to an electrical power source, shown in general by the reference numeral 24. The power source 24 operates in a conventional manner to apply alternating current at a predetermined frequency and power level to the wire assembly 10 for a predetermined time. As a non-limitive example, the alternating current is adjusted to a frequency of 34.518 MHZ and at a power level of seventy watts and is conducted through the wire assembly 10 for six minutes.

An alternating magnetic field is thus generated by the electrical current and the susceptor particles in the composite layer 16 (Fig. 1) of the wire assembly 10 absorb the resultant energy which, in turn, causes the susceptor particles to heat up and initially heat the polyethylene material in the layer 16 which contains the particles. This heat is conducted through the outer layer 18, and to the opposed surface areas of the polyethylene sheets 20 and 22, that is, the lower surface of the sheet 20 and the upper surface area of the sheet 22 along the bond line L. The polyethylene forming the latter surface areas of the sheets 20 and 22 melts and flows together and, when the current is removed, the bond site cools and the bond is complete. The layers 14 and 18 also melt during the above process, with the inner layer functioning to insulate the susceptor particles from the bare wire 12 thus preventing shorting of the electrical current passing through the wire, and the outer layer 18 functioning to promote a uniform melting of the opposed surface areas of the sheets 20 and 22. The above-mentioned pieces or rods (not shown) of polyethylene filler material that are used to fill that part of the channel 22a not filled

by the wire assembly 10 also melt during the above process.

The wire assembly 10 is particularly effective and efficient for generating heat in a bonding application. As may be understood, the extrusion of the thermoplastic material containing the electromagnetic susceptor particles causes the susceptor particles to be dispersed in close proximity to the wire 12 around the wire 12. Furthermore, if the susceptor particles are generally planar, as is the case with ferrites and certain other susceptor particles, the susceptor particles tend to orient themselves with their planar surfaces parallel to the wire 12 because of the extrusion process. That is, the forces during extrusion are largely directed parallel to the longitude of the wire. The susceptor particles orient themselves in the position of least resistance, which happens to be with their planar surfaces parallel to the wire 12. That orientation of the susceptor particles is ideal for maximum magnetic field absorption and, thus, heating with great efficiency. Beyond that, the location of the susceptor particles around the wire 12 optimizes the absorption capability because the field generated by the current flowing through the wire 12 is lost, for purposes of heating, only if it passes through the dispersed particles encircling the wire 12. Because minimal field is lost in this manner given the location of the susceptor particles around the wire, a superior efficiency of energy is achieved. In sum, the close proximity of the susceptor particles to the wire 12 around the wire 12 and the orientation of the susceptor particles because of the extrusion process provide a substantially maximum field strength at the wire assembly 10 when subjected to the alternating magnetic field.

Also, the effective surface area so heated when the wire assembly 10 is employed is much greater than merely that of the wire 12. The result is that, during heating by the alternating magnetic field, the wire 12 is maintained at a much lower surface temperature with resulting improved reliability of the heating achieved. In fact, the wire 12 temperature would not necessarily rise above the total melt temperature and the resistance of the wire could be used to indicate overall bond line temperature rise.

Another embodiment of the wire assembly of the present invention is shown

in Fig. 5 in connection with the sheet 22. According to the embodiment of Fig. 5, a wire assembly 10' is provided which is identical to the wire assembly 10 in the embodiment of Fig. 1 with the exception that the wire assembly 10' is approximately twice the length of the wire assembly 10 and is configured in a double-back loop. Thus, when the sheets 20 and 22 are to be bonded together, two sections of the wire assembly 10' would be place in the channel 22a, that is, the regular section as shown in Fig. 3 and the doubled-back section. The projecting end portions of the wire 10' extend through the opening 22b for connection to the power source 24 (Fig. 5). Pieces or rods of a polyethylene filler material would be used to separate the sections of the wire assembly 10' and completely fill the channel 22a. As a non-limitive example of the power applied to the wire assembly 10a, the alternating current would be at a frequency of 29.250 MHZ and at a power level of 70.9 watts and would be conducted through the wire assembly 10' for ten minutes. Otherwise the bonding operation of the embodiment of Fig. 5 is identical to that of the previous embodiment.

As is understood, the double-back loop configuration of the wire assembly 10' provides certain advantages. In particular, the electromagnetic field generated by the current through the wire 12 is even more efficiently utilized for heating because of the close proximity of the susceptor particles of both of the respective sides of the loop. That is, certain of the field which passes through the composite layer 16 of one side of the loop without being absorbed by susceptor particles may be absorbed by the composite layer of the other side of the loop. Additionally, the double-back loop configuration reduces the resulting radiation because a lower antenna aperture is possible.

Another alternate embodiment of the wire assembly of the present invention is shown by the reference numeral 10" in Fig. 6 and contains materials and components that are identical to those of the embodiment of Fig. 1, which are given the same reference numerals. The wire assembly 10" is the same as the wire assembly 10 depicted in Fig. 1 with the exception that the outer polyethylene layer 18 is omitted. Therefore, this embodiment is less costly than that of the previous

embodiment, although sacrificing some uniformity of heating, as described above.

The advantages of the present invention are many. For example, the wire assemblies and the method of the present invention are particularly applicable for bonding applications in which the heating must be confined to an area that is not easily accessible or to an area near the bond line. Further, the wire assemblies and method of the present invention achieve uniform heating in an efficient manner.

It is understood that the present invention has been described in connection with the thermal bonding of the polyethylene sheets 20 and 22 for the purpose of example only and that other objects in other configurations and consisting of other materials may be bonded without departing from the scope of the invention. In this context, only one of the objects to be bonded may be formed of the thermoplastic material and may be formed of a material only a portion of which is thermoplastic. Also, the present invention is not limited to the specific location of the wire assembly relative to the objects to be bonded, i.e., the sheets 20 and 22 in the example shown, as long as the wire 12 is positioned close enough to the object or objects to enable the heat energy from the magnetic susceptors in the layer 16 to be absorbed by the object or objects. Further, the present invention is equally applicable to thermoset adhesive bonding in which the pieces to be bonded would be provided with a coating of a conventional thermoset adhesive and the wire assemblies of the present invention would be used to activate and melt the adhesive in the foregoing manner. Still further, the specific frequency and amount of power applied to the wire assembly 10, as well as the duration of the application of the power, can be varied within the scope of the invention.

It is understood that the present invention is not limited to the particular materials and dimensions of the wire assemblies set forth above. Also, the wire assemblies and method of the present invention are not limited to the bonding of two sheets as described above for the purposes of example, but have many other applications. For example, the wire assemblies and method of the present invention can be used to form enclosures that provide physical protection of cables and splices used in an outside environment as in the communications industry. Of

course, as previously mentioned, the cables referred to herein may be any type of communications cables, such as electrical, optical, or others, for which it is desirable to provide seals. Another application of the wire assemblies and method of the present invention is the sealing of piping material such as the ones used in the gas industry.

It is also understood that the embodiments of the assembly of the present invention described above are intended to illustrate rather than limit the invention, and that the wire assemblies and methods disclosed above can take many other forms and embodiments within the scope of the invention.

Claims

What is claimed is:

1. A method of bonding a first object containing a thermoplastic material to another object, the method comprising the steps of applying a layer of thermoplastic material containing susceptor particles over an electrical conductor, placing the electrical conductor in proximity to the first object, applying electrical energy to the electrical conductor to create an alternating magnetic field, and controlling the amount of electrical energy applied in the step of applying so that the susceptor particles absorb the energy from the magnetic field and heat up and melt the thermoplastic material of the first object to enable the first object to be bonded to the other object.

2. The method of claim 2 further comprising the step of terminating the application of the electrical energy to the conductor when a predetermined portion of the thermoplastic material of the first object has melted so that the melted thermoplastic material cools to bond the first object to the other object.

3. The method of claim 1 wherein the other object is also formed of a thermoplastic material and is positioned in a heat exchange relationship to the electrical conductor so that the thermoplastic material of the other object is also heated and melted and flows with the thermoplastic material of the first object to promote the bonding.

4. The method of claim 1 wherein the layer of thermoplastic material containing the susceptor particles is extruded over the electrical conductor.

5. The method of claim 1 further comprising the step of applying an inner layer of thermoplastic material over the electrical conductor before the step of

applying the layer of thermoplastic material containing susceptor particles over the electrical conductor.

6. The method of claim 5 wherein the inner layer of thermoplastic material is extruded over the electrical conductor and wherein the layer of thermoplastic material containing susceptor particles is extruded over the inner layer.

7. The method of claim 1 or 6 further comprising the step of applying an outer layer of thermoplastic material over the layer of thermoplastic material containing susceptor particles.

8. The method of claim 7 wherein the outer layer of thermoplastic material is extruded over the layer of thermoplastic material containing the electrical conductor.

9. The method of claim 1 further comprising the step of forming a channel in the first object which extends around the periphery of the first object, and placing the electrical conductor in the channel.

10. The method of claim 1 wherein the electrical conductor is doubled over so that two lengths of the electrical conductor are concurrently placed in proximity to the first object.

11. A method of bonding a first object to another object, the method comprising the steps of applying a layer of thermoset adhesive to the first object, applying a layer of thermoplastic material containing susceptor particles over an electrical conductor, placing the electrical conductor in proximity to the first object, applying electrical energy to the electrical conductor to create an alternating magnetic field, and controlling the amount of electrical energy applied in the step of

applying so that the susceptor particles absorb the energy from the magnetic field and heat up and melt the adhesive to enable the first object to be bonded to the other object.

12. The method of claim 11 further comprising the step of terminating the application of the electrical energy to the conductor when a predetermined portion of the adhesive has melted so that the melted adhesive cools to bond the first object to the other object.

13. The method of claim 11 further comprising the step of applying a thermoset adhesive to the other object, and placing the electrical conductor in a heat exchange relationship to the second object so that the adhesive on the other object is also heated and melted and flows with the adhesive on the first object to promote the bonding.

14. The method of claim 11 further comprising the step of forming a channel in the first object which extends around the periphery of the first object, and placing the electrical conductor in the channel.

15. The method of claim 14 wherein the electrical conductor is doubled over in the channel so that two lengths of the electrical conductor extend in the channel.

16. A wire assembly comprising an electrical conductor, a layer of thermoplastic material containing susceptor particles extending over the electrical conductor, and a source of electrical energy connected to the electrical conductor to create an alternating magnetic field so that the susceptor particles absorb the energy from the magnetic field and heat up and melt the thermoplastic material.

17. The assembly of claim 16 wherein the layer of thermoplastic material

containing the susceptor particles is extruded over the electrical conductor.

18. The assembly of claim 16 further comprising an inner layer of thermoplastic material extending between the electrical conductor and the layer of thermoplastic material containing susceptor particles.

19. The assembly of claim 18 further comprising an outer layer of thermoplastic material extending over the layer of thermoplastic material containing susceptor particles.

20. The assembly of claim 16 further comprising an outer layer of thermoplastic material extending over the layer of thermoplastic material containing susceptor particles.

21. A wire assembly, comprising:

a wire; and

a composite sheath of a thermoplastic and susceptor particles surrounding the wire.

22. The wire assembly of claim 21, wherein the wire is an electrical conductor.

23. A method of heating, comprising:

coating a wire with a composite sheath of a thermoplastic and susceptor particles; and

generating a field in the vicinity of the wire, for absorption by the susceptor particles.

24. The method of claim 23, wherein the wire is an electrical conductor.

25. A method of bonding a first object to a second object, comprising the steps of:

providing a wire;

locating susceptor particles around the wire; and

generating a magnetic field for absorption by the susceptor particles.

26. The method of claim 25, further comprising the step of placing the wire near an interface of the first object and the second object.

27. The method of claim 25, wherein the susceptor particles have a planar surface that is oriented parallel to the wire in the step of locating.

28. The method of claim 25, further comprising the step of orienting the susceptor particles having a planar surface with the planar surface parallel to the wire.

29. The method of claim 25, comprising the step of double-back looping the wire.

30. An assembly, comprising:

a generally cylindrical conductor; and

susceptor means located around the generally cylindrical conductor.

31. The assembly of claim 30, further comprising a thermoplastic in which the susceptor means is dispersed.

32. The assembly of claim 30, further comprising a thermoplastic located around the generally cylindrical conductor between the generally cylindrical conductor and the susceptor means.

33. The assembly of claim 30, wherein the generally cylindrical conductor has a generally square cross-section.

34. The wire assembly of claim 21, further comprising a plurality of composite sheaths each of a different thermoplastic and susceptor particles surrounding the wire, the different thermoplastic of each having a respective melt temperature.

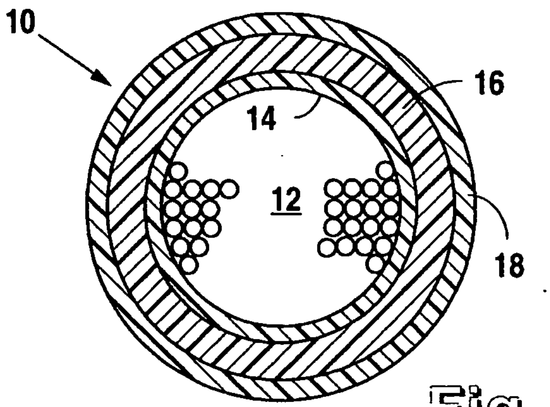

Fig. 1

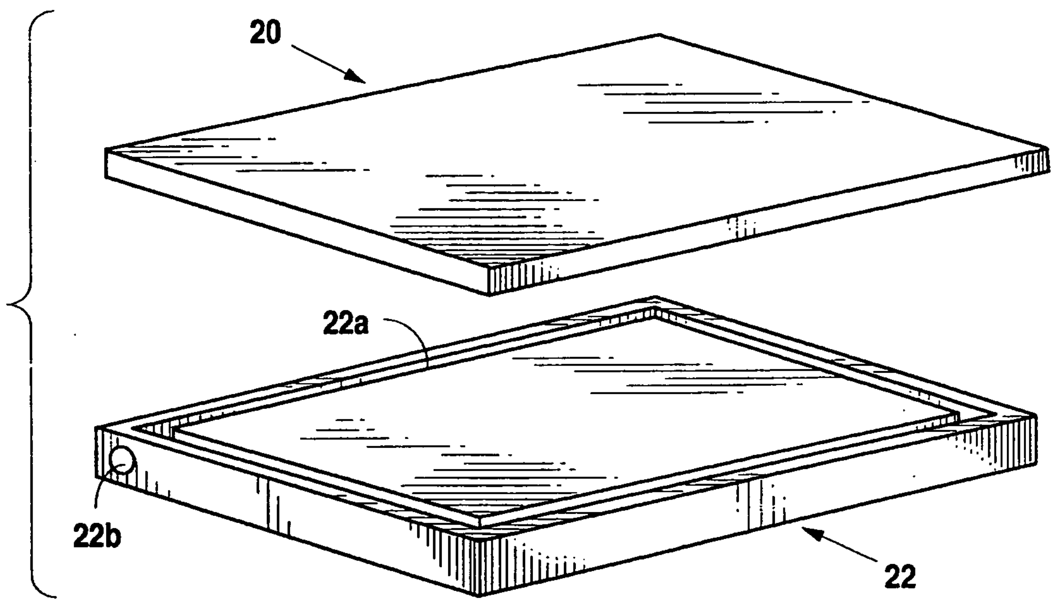

Fig. 2

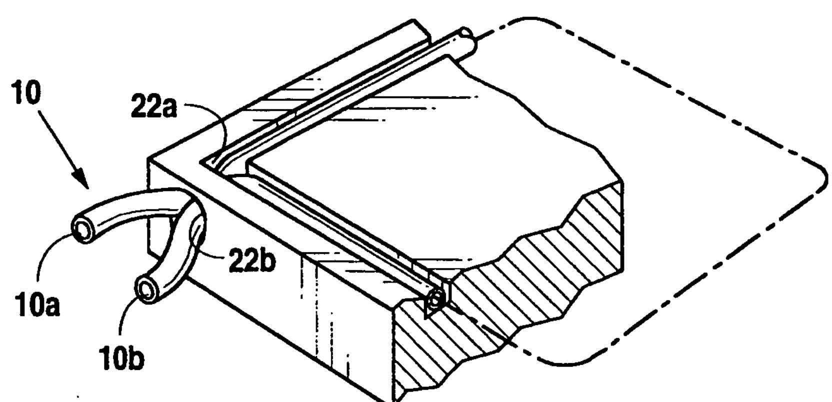

Fig. 3

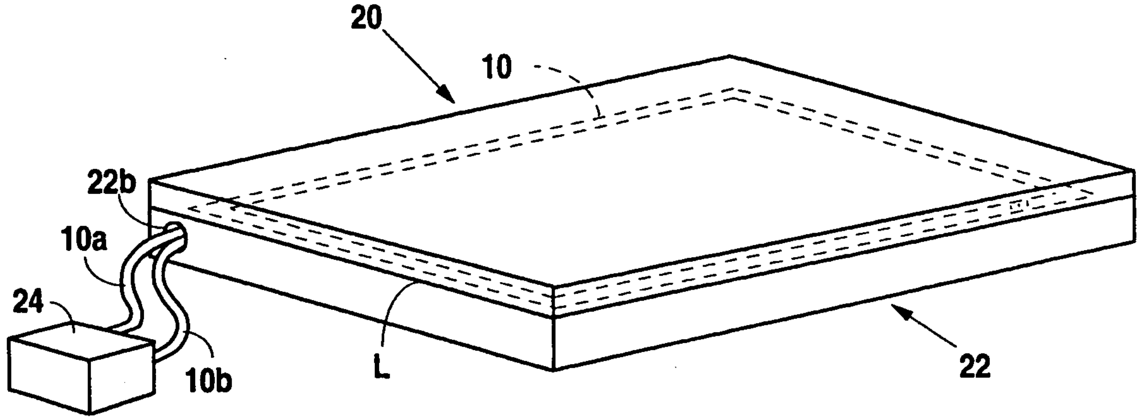

Fig. 4

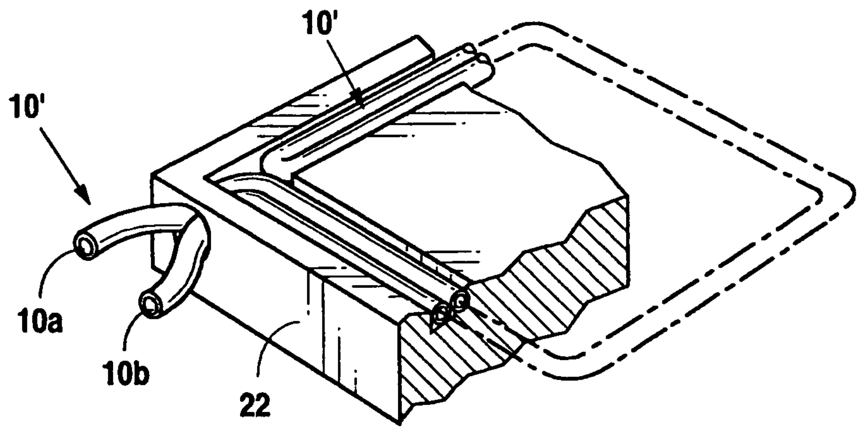

Fig. 5

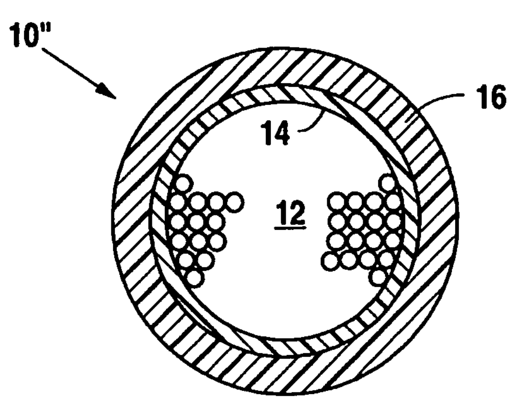

Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/04575

A. CLASSIFICATION OF SUBJECT MATTER

B 29 C 65/02,H 05 B 6/10,3/56

According to International Patent Classification (IPC) or to both national classification and IPC 6

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B 29 C,H 05 B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5125690 A (TAYLOR) 30 June 1992 (30.06.92), abstract, column 5, lines 15-55, column 6, lines 7-29, claim 1, fig. 1,2. --	1,11, 16,18, 19
A	US 3620875 A (GUGLIELMO, R.J.) 28 July 1969 (28.07.69), abstract, column 3, lines 44-51, column 3, line 66 - column 4, line 10, column 4, lines 28-36,52-72, claims 1,4,7. --	1,11, 16
A	WO 93/18890 A1 (MINNESOTA) 30 September 1993	1,4-6, 11,16,

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

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20 October 1997	31.10.97

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	(30.09.93), abstract, page 10, line 12 - page 11, line 6, page 17, lines 9-15, fig. 1,2,4. --	17,21-24,30, 31
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ANHANG	ANNEX	ANNEXE
zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.	to the International Search Report to the International Patent Application No.	au rapport de recherche international relatif à la demande de brevet international n°

PCT/US 97/04575 SAE 158260

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.	This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The Office is in no way liable for these particulars which are given merely for the purpose of information.	La presénte annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche international visée ci-dessus. Les reseignements fournis sont donnés à titre indicatif et n'engagent pas la responsibilité de l'Office.

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